Phantom motor execution facilitated by machine learning and augmented reality as treatment for phantom limb pain: a single group, clinical trial in patients with chronic intractable phantom limb pain


With machine learning, augmented reality and gaming compared to traditional treatment for phantom limb pain:

- Pain intensity was decreased by 51%.
- Pain duration was decreased by 47%.
- All patients experienced reduction in quality of pain.
- Pain sleep and activities of daily living intrusions were reduced on average by 61% and 43%, respectively.
- Pain sensations, such as stabbing and tiring-exhausting, were significantly less prevalent after treatment.
- Improvements remained 6 months after treatment.

On the graph, the perception of phantom limb pain intensity, weight distribution, activities of daily living (ADL) and sleep pain intrusion are compared after the 1st treatment session and 6 months after therapy. The pain intensity (measured by pain rating index) was decreased by 51%, weight pain distribution by 47%, while pain sleep and activities of daily living intrusions were reduced on average by 61% and 43% respectively.
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Population

Subjects: 14 (7 transhumeral, 2 of them bilateral; 7 transradial) patients with upper limb amputation afflicted by refractory chronic phantom limb pain

Previous prosthesis: n.a.
Amputation causes: 12 trauma, 1 infection, 1 tumor
Mean age: 50.3 years (± 10.3 years)
Mean time since amputation: 10.4 years (± 11.1 years)

Study Design

Interventional pre- to post-test design:

Patients with upper limb amputation afflicted by refractory chronic phantom limb pain

All patients received an intervention twice per week except for one who had it daily. Each session lasted 2 h and consisted of (1) pain evaluation, (2) placement of the electrodes and marker, (3) practice motor execution in augmented reality, (4) gaming by racing car using phantom movements, and (5) matching random target postures of a virtual arm in virtual reality.

Results

<table>
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<tr>
<th>Body Function</th>
<th>Activity</th>
<th>Participation</th>
<th>Others</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mechanics</td>
<td>Pain</td>
<td>Grip patterns / force</td>
<td>Manual dexterity</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Activities of daily living (ADL)</td>
<td>Satisfaction and Quality of life (QoL)</td>
</tr>
<tr>
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<td>Training</td>
<td>Technical aspect</td>
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</tbody>
</table>

Category

Outcomes

Results for machine learning, augmented reality and gaming vs. traditional treatment for phantom limb pain

Sig.*

Pain

Pain rating index

Significant reduction of pain intensity by 51%.

All patients experienced reduction in quality of pain. Pain sensations, such as stabbing and tiring–exhausting, were significantly less prevalent after treatment.

Reduction in pain intensity was maintained at all of follow-up visits. The average improvement measured at the last treatment session decreased by 2%, 6%, and 24% at 1, 3, and 6 month follow-ups, respectively.

Numeric rating scale of phantom limb pain

Significant reduction of pain intensity by 32%.

9 patients (64%) experienced reduction of pain intensity.

Weighted pain distribution

Pain sleep and activities of daily living intrusions were reduced on average by 61 and 43%, respectively.

Significant reduction of pain duration by
Phantom motor execution facilitated by machine learning and augmented reality as treatment for phantom limb pain:

<table>
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<th>Category</th>
<th>Outcomes</th>
<th>Results for machine learning, augmented reality and gaming vs. traditional treatment for phantom limb pain</th>
<th>Sig.*</th>
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<tbody>
<tr>
<td>Pain medication</td>
<td>Intake of pain medication was reduced at last treatment in 2 of 4 patients.</td>
<td>12 patients (86%) experienced reduction of pain weight distribution.</td>
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</tr>
</tbody>
</table>

*no difference (0), positive trend (+), negative trend (−), significant (++/−−), not applicable (n.a.)

**Author’s Conclusion**

“We introduce a novel plasticity-based, non-invasive treatment for phantom limb pain, in which phantom motor execution is decoded via machine learning, while visualisation of the phantom is accomplished via augmented and virtual reality. These technological features overcome previous limitations of plasticity-based treatments, such as mirror therapy, while enhancing patient engagement via serious gaming. Reversal of cortical reorganisation and competitive plasticity are hypothesised to be the mechanisms of action of the approach presented here.” (Ortiz-Catalan et al. 2016)